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(54) **SELECTIVE ROBUST HEADER COMPRESSION (ROHC) FOR A VOIP CALL IN A CELLULAR COMMUNICATIONS NETWORK**

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H04L 29/06 (2006.01)
H04W 28/06 (2009.01)

(52) **U.S. Cl.**

CPC ***H04W 28/06*** (2013.01); ***H04L 65/00*** (2013.01); ***H04L 65/607*** (2013.01); ***H04L 69/04*** (2013.01); ***H04L 69/22*** (2013.01); ***H04W 76/00*** (2013.01)

(58) **Field of Classification Search**

None

See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

2009/0022107 A1*	1/2009	Kapoor	H04L 69/04 370/331
2010/0322151 A1*	12/2010	Racz	H04W 28/06 370/328
2014/0064156 A1*	3/2014	Paladugu et al.	370/259

FOREIGN PATENT DOCUMENTS

WO 2010002767 A1 1/2010

OTHER PUBLICATIONS

Bormann, Carsten et al., "RObust Header Compression (ROHC): Framework and four profiles: RTP, UDP, ESP, and uncompressed," Internet-Draft, Network Working Group, Internet Engineering Task Force, Feb. 26, 2001, The Internet Society, 154 pages.

(Continued)

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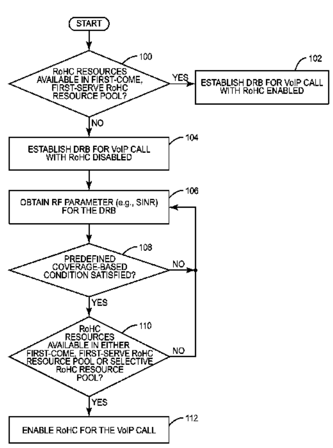
(57) **ABSTRACT**

Systems and methods for selectively enabling Robust Header Compression (RoHC) for Voice over Internet Protocol (VoIP) calls in a cellular communications network are disclosed. In one embodiment, a data radio bearer for a VoIP call is established between a base station and a mobile terminal. During the VoIP call, a radio frequency parameter for the data radio bearer is monitored. When the radio frequency parameter for the data radio bearer satisfies a predefined coverage-based condition, the base station enables RoHC for the VoIP call. In one preferred embodiment, the radio frequency parameter is a Signal-to-Interference-plus-Noise Ratio (SINR) for the data radio bearer for the VoIP call, and the predefined coverage-based condition is a predefined SINR threshold below which the base station enables RoHC. By enabling RoHC in this manner, RoHC resources are selectively made available for those VoIP calls that will benefit most from increased cell coverage provided by RoHC.

18 Claims, 6 Drawing Sheets

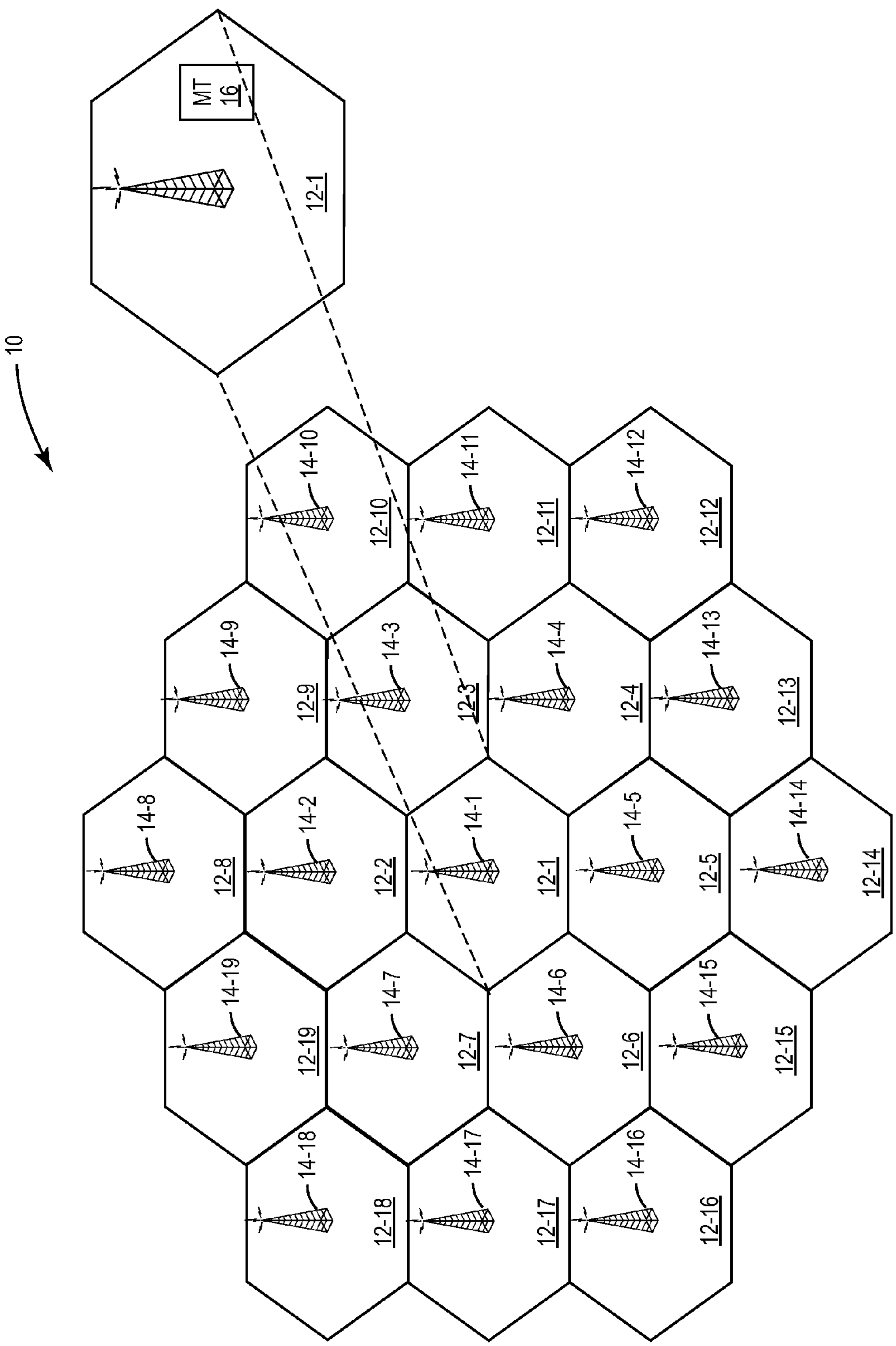


(56) **References Cited**

OTHER PUBLICATIONS

Rein, Stephan et al., "Voice Quality Evaluation in Wireless Packet Communication Systems: A Tutorial and Performance Results for ROHC," IEEE Wireless Communications, vol. 12, Issue 1, Feb. 2005, IEEE, pp. 60-67.
International Search Report and Written Opinion for Application No. PCT/IB2013/059019, mailed Jun. 2, 2014, 11 pages.
Author Unknown, "ETSI TS 136 321", European Telecommunications Standards Institute, Oct. 2012, Version 11.0.0, Release 11, 57 pages, France.
Author Unknown, "ETSI TS 136 331", European Telecommunications Standards Institute, Nov. 2012, Version 11.1.0, Release 11, 329 pages, France.
International Preliminary Report on Patentability for International Patent Application No. PCT/IB2013/059019, mailed May 28, 2015, 8 pages.

* cited by examiner


10
MT
16
12-1
14-1
14-2
14-3
14-4
14-5
14-6
14-7
14-8
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14-10
14-11
14-12
14-13
14-14
14-15
14-16
14-17
14-18
14-19
12-1
12-2
12-3
12-4
12-5
12-6
12-7
12-8
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12-18
12-19

FIG. 1

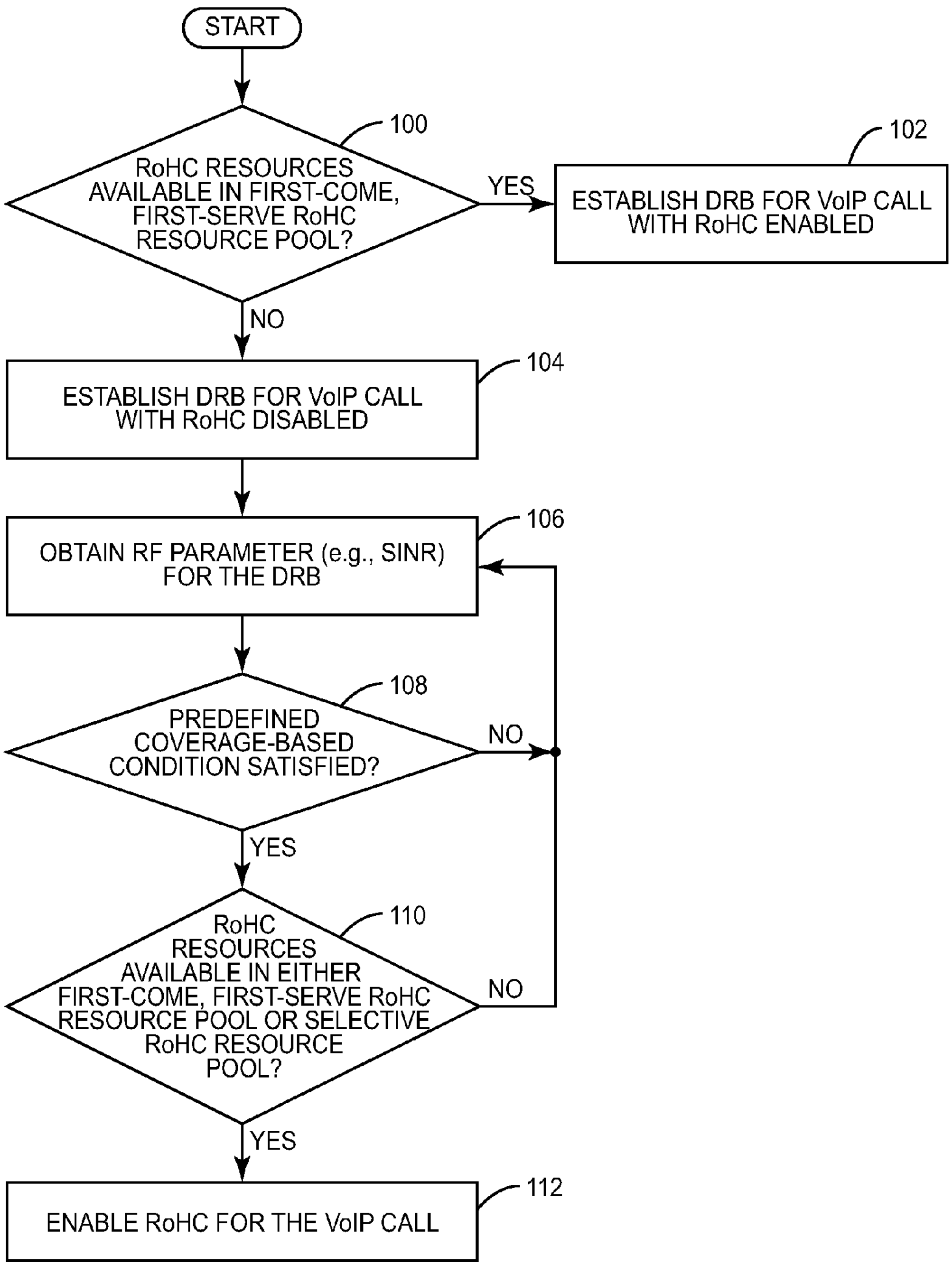
START
100
RoHC RESOURCES AVAILABLE IN FIRST-COME, FIRST-SERVE RoHC RESOURCE POOL?
YES
102
ESTABLISH DRB FOR VoIP CALL WITH RoHC ENABLED
NO
104
ESTABLISH DRB FOR VoIP CALL WITH RoHC DISABLED
106
OBTAIN RF PARAMETER (e.g., SINR) FOR THE DRB
108
PREDEFINED COVERAGE-BASED CONDITION SATISFIED?
NO
YES
110
RoHC RESOURCES AVAILABLE IN EITHER FIRST-COME, FIRST-SERVE RoHC RESOURCE POOL OR SELECTIVE RoHC RESOURCE POOL?
NO
YES
112
ENABLE RoHC FOR THE VoIP CALL

FIG. 2

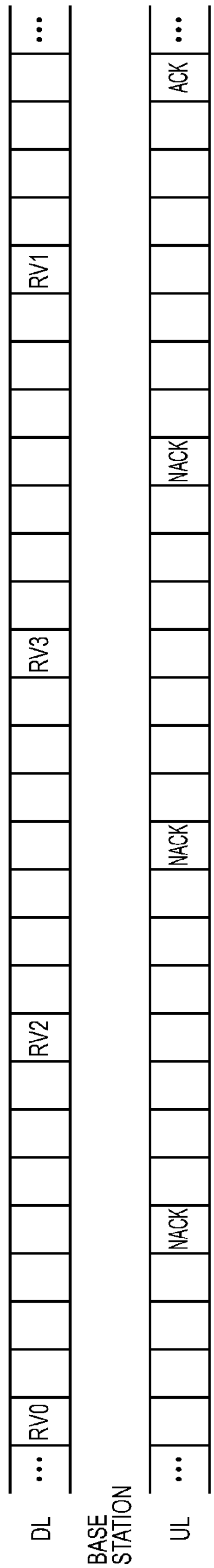
DL
BASE STATION
UL
RV0
RV2
RV3
RV1
NACK
NACK
NACK
ACK

FIG. 3A

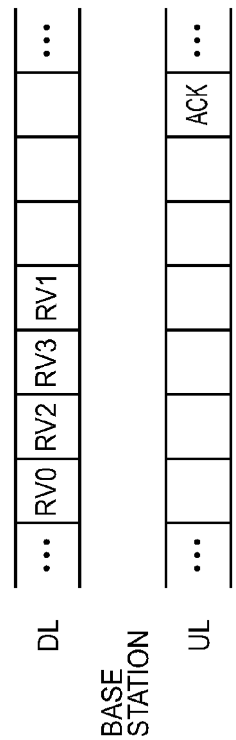
DL
BASE STATION
UL
RV0
RV2
RV3
RV1
ACK

FIG. 3B

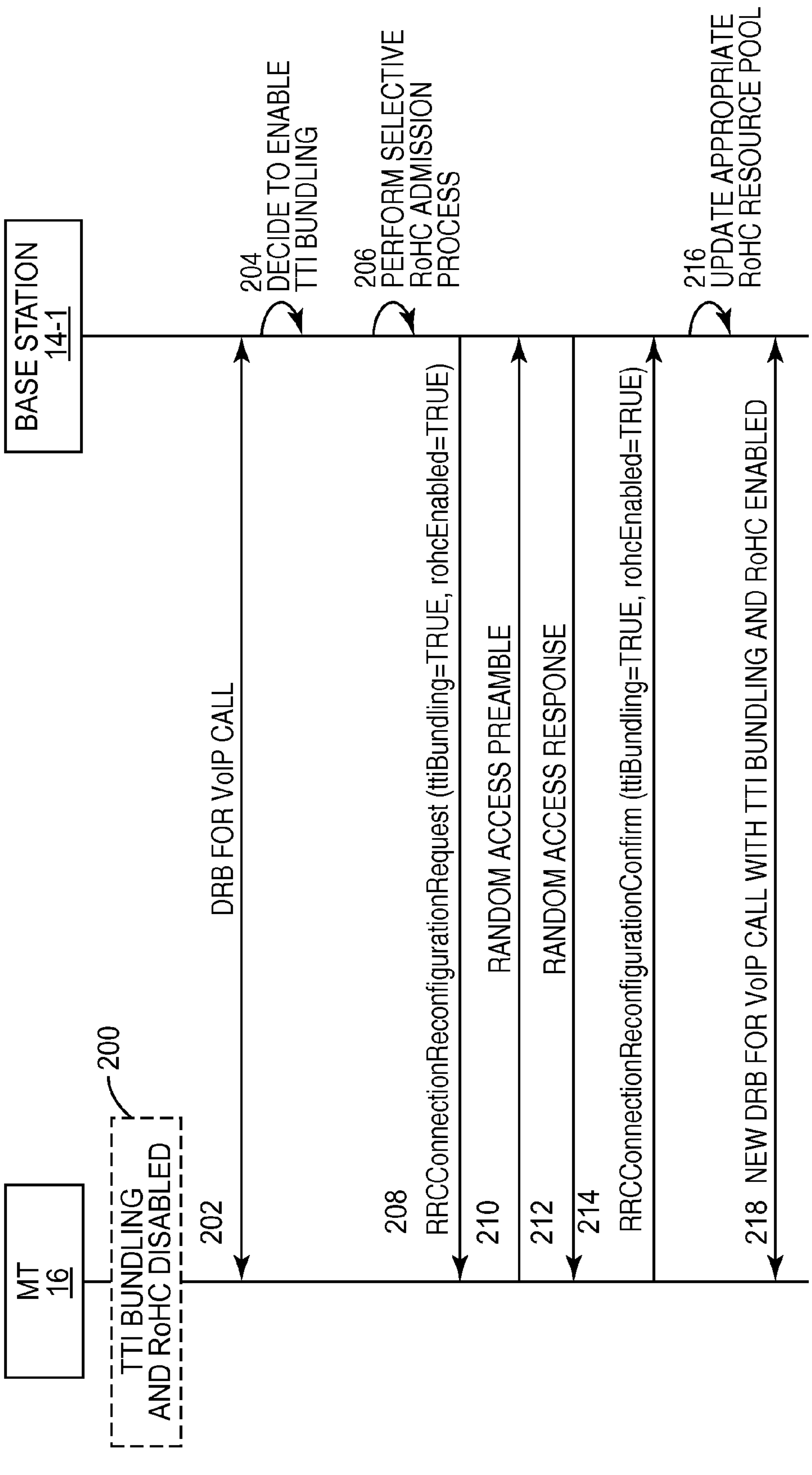
BASE STATION
14-1
MT
16
TTI BUNDLING AND RoHC DISABLED
200
202
DRB FOR VoIP CALL
204
DECIDE TO ENABLE TTI BUNDLING
206
PERFORM SELECTIVE RoHC ADMISSION PROCESS
208
RRCConnectionReconfigurationRequest (ttiBundling=TRUE, rohcEnabled=TRUE)
210
RANDOM ACCESS PREAMBLE
212
RANDOM ACCESS RESPONSE
214
RRCConnectionReconfigurationConfirm (ttiBundling=TRUE, rohcEnabled=TRUE)
216
UPDATE APPROPRIATE RoHC RESOURCE POOL
218
NEW DRB FOR VoIP CALL WITH TTI BUNDLING AND RoHC ENABLED

FIG. 4

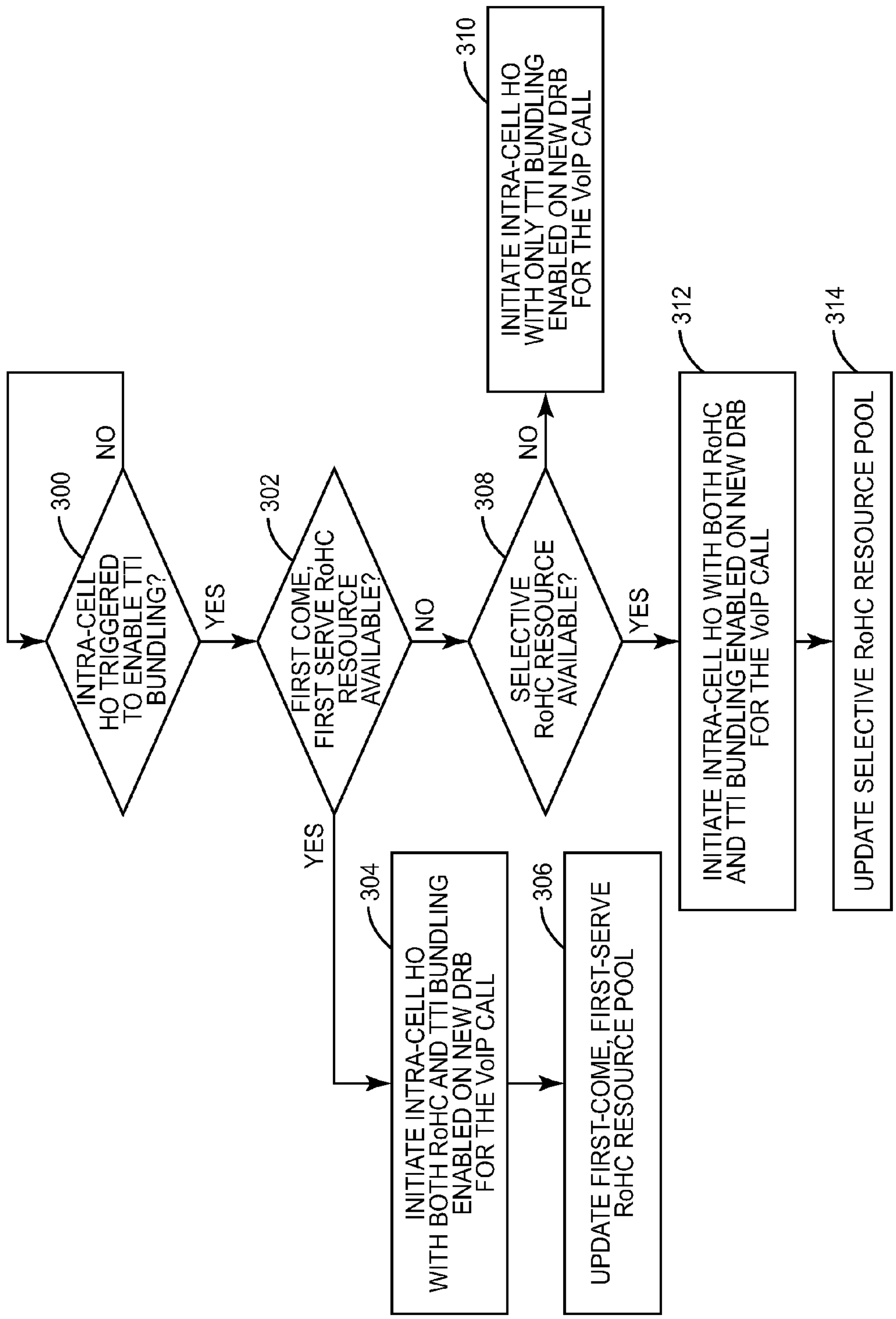
300
INTRA-CELL HO TRIGGERED TO ENABLE TTI BUNDLING?
NO
YES
302
FIRST COME, FIRST SERVE RoHC RESOURCE AVAILABLE?
YES
NO
304
INITIATE INTRA-CELL HO WITH BOTH RoHC AND TTI BUNDLING ENABLED ON NEW DRB FOR THE VoIP CALL
306
UPDATE FIRST-COME, FIRST-SERVE RoHC RESOURCE POOL
308
SELECTIVE RoHC RESOURCE AVAILABLE?
NO
YES
310
INITIATE INTRA-CELL HO WITH ONLY TTI BUNDLING ENABLED ON NEW DRB FOR THE VoIP CALL
312
INITIATE INTRA-CELL HO WITH BOTH RoHC AND TTI BUNDLING ENABLED ON NEW DRB FOR THE VoIP CALL
314
UPDATE SELECTIVE RoHC RESOURCE POOL

FIG. 5

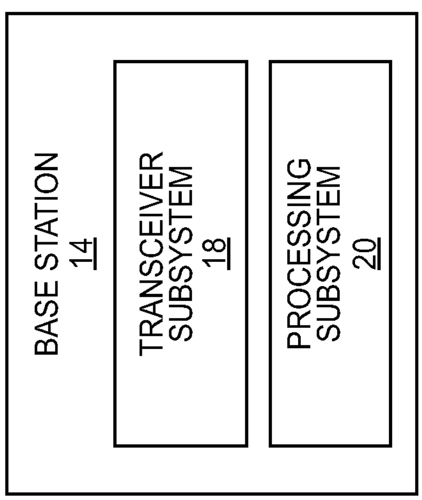
BASE STATION
14
TRANSCEIVER SUBSYSTEM
18
PROCESSING SUBSYSTEM
20

FIG. 6

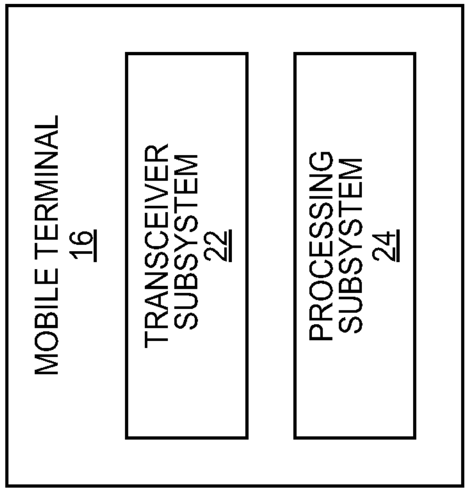
MOBILE TERMINAL
16
TRANSCEIVER SUBSYSTEM
22
PROCESSING SUBSYSTEM
24

FIG. 7

SELECTIVE ROBUST HEADER COMPRESSION (ROHC) FOR A VOIP CALL IN A CELLULAR COMMUNICATIONS NETWORK

FIELD OF THE DISCLOSURE

The present disclosure relates generally to Voice over Internet Protocol (VoIP) calls in a cellular communications network and more particularly relates to Robust Header Compression (RoHC) for VoIP calls in a cellular communications network.

BACKGROUND

Voice over data networks has been seen as the next step in the evolution of wireless voice in cellular communications networks. The preferred protocol for enabling this evolution is Voice over Internet Protocol (VoIP). When using VoIP, each voice frame is routed using an Internet Protocol (IP) header. The IP header for VoIP is considerably larger than the very small header used for transporting voice traffic over the air in traditional 2G/3G cellular communications networks. This implies that the header overhead to payload ratio when using VoIP is much larger than that in traditional 2G/3G cellular communications networks, which is undesirable. One solution to this problem is the use of Robust Header Compression (RoHC) to compress the IP header before the IP header is transmitted over the air.

One key benefit of RoHC when used with VoIP in Long Term Evolution (LTE) cellular communications networks is improved cell coverage for VoIP users. In particular, RoHC decreases the number of bits needed per VoIP packet, thus decreasing the risk that VoIP packet segmentation will occur. This translates into a path-loss improvement, which in turn increases the cell coverage for the VoIP user.

RoHC is a resource intensive application. In other words, RoHC requires a significant amount of resources (i.e., processing cycles and memory) at a base station in a cellular communications network. One issue that arises when using RoHC with VoIP is that the base station may not have sufficient resources to enable RoHC for all VoIP calls. As such, there is a need for systems and methods that selectively enable RoHC for VoIP calls in a cellular communications network.

SUMMARY

The present disclosure relates to systems and methods for selectively enabling Robust Header Compression (RoHC) for Voice over Internet Protocol (VoIP) calls in a cellular communications network. In one embodiment, a data radio bearer for a VoIP call is established between a base station and a mobile terminal. During the VoIP call, a radio frequency parameter for the data radio bearer is monitored. When the radio frequency parameter for the data radio bearer satisfies a predefined coverage-based condition, the base station enables RoHC for the VoIP call. In one preferred embodiment, the radio frequency parameter is a Signal-to-Interference-plus-Noise Ratio (SINR) for the data radio bearer for the VoIP call, and the predefined coverage-based condition is a predefined SINR threshold below which the base station enables RoHC. Still further, in one particular embodiment, the predefined SINR threshold is a predefined SINR threshold below which the base station enables Transmit Time Interval (TTI) bundling. By enabling RoHC in this

manner, RoHC resources are selectively made available for those VoIP calls that will benefit most from increased cell coverage provided by RoHC.

In one embodiment, a base station has a finite amount of RoHC resources (i.e., processor cycles and memory resources) that are available for RoHC. The RoHC resources are logically divided into a first-come, first-serve RoHC resource pool and a selective RoHC resource pool. A data radio bearer for a VoIP call is established between the base station and a mobile terminal. During the VoIP call, a radio frequency parameter for the data radio bearer is monitored. When the radio frequency parameter for the data radio bearer satisfies a predefined coverage-based condition, the base station performs a selective RoHC admission process. In one preferred embodiment, the radio frequency parameter is a SINR for the data radio bearer for the VoIP call, and the predefined coverage-based condition is a predefined SINR threshold below which the base station enables RoHC. Still further, in one particular embodiment, the predefined SINR threshold is a predefined SINR threshold below which the base station enables TTI bundling. As a result of the selective RoHC admission process, the base station enables RoHC for the VoIP call if there are available RoHC resources in either the first-come, first-serve RoHC resource pool or the selective RoHC resource pool. Conversely, if there are no available RoHC resources in the first-come, first-serve RoHC resource pool and the selective RoHC resource pool, the base station does not enable RoHC for the VoIP call.

In another embodiment, a data radio bearer for a VoIP call is established between the base station and a mobile terminal. During the VoIP call, a SINR for the data radio bearer is monitored. When the SINR for the data radio bearer falls below a predefined threshold for triggering TTI bundling, the base station performs an intra-cell handover procedure to establish a new data radio bearer for the VoIP call in which both TTI bundling and RoHC are enabled.

In yet another embodiment, a base station has a finite amount of RoHC resources (i.e., processor cycles and memory resources) that are available for RoHC. The RoHC resources are logically divided into a first-come, first-serve RoHC resource pool and a selective RoHC resource pool. A data radio bearer for a VoIP call is established between the base station and a mobile terminal. During the VoIP call, a SINR for the data radio bearer is monitored. When the SINR for the data radio bearer falls below a predefined threshold for triggering TTI bundling, the base station performs a selective RoHC admission process. As a result of the selective RoHC admission process, the base station determines that RoHC is to be enabled for the VoIP call if there are available RoHC resources in either the first-come, first-serve RoHC resource pool or the selective RoHC resource pool. Conversely, if there are no available RoHC resources in the first-come, first-serve RoHC resource pool and the selective RoHC resource pool, the base station determines that RoHC is not to be enabled for the VoIP call. The base station then performs an intra-cell handover procedure to establish a new data radio bearer for the VoIP call in which TTI bundling is enabled and RoHC is enabled or disabled according to the result of the selective RoHC admission process.

Those skilled in the art will appreciate the scope of the present disclosure and realize additional aspects thereof after reading the following detailed description of the preferred embodiments in association with the accompanying drawing figures.

BRIEF DESCRIPTION OF THE DRAWING FIGURES

The accompanying drawing figures incorporated in and forming a part of this specification illustrate several aspects of the disclosure, and together with the description serve to explain the principles of the disclosure.

FIG. **1** illustrates a cellular communications network providing selective Robust Header Compression (RoHC) for Voice over Internet Protocol (VoIP) calls according to one embodiment of the present disclosure;

FIG. **2** is a flow chart that illustrates the operation of a base station to selectively enable RoHC for a VoIP call according to one embodiment of the present disclosure;

FIGS. **3**A and **3**B graphically illustrate a Hybrid Automatic Repeat Request (HARQ) transmission scheme without and with Transmit Time Interval (TTI) bundling;

FIG. **4** illustrates the operation of a base station to perform an intra-cell handover to enable both TTI bundling and RoHC for a VoIP call according to one embodiment of the present disclosure;

FIG. **5** is a flow chart that illustrates the operation of a base station to selectively enable RoHC for a VoIP call according to another embodiment of the present disclosure;

FIG. **6** is a block diagram of a base station according to one embodiment of the present disclosure; and

FIG. **7** is a block diagram of a mobile terminal according to one embodiment of the present disclosure.

DETAILED DESCRIPTION

The embodiments set forth below represent the necessary information to enable those skilled in the art to practice the embodiments and illustrate the best mode of practicing the embodiments. Upon reading the following description in light of the accompanying drawing figures, those skilled in the art will understand the concepts of the disclosure and will recognize applications of these concepts not particularly addressed herein. It should be understood that these concepts and applications fall within the scope of the disclosure and the accompanying claims.

The present disclosure relates to systems and methods for selective Robust Header Compression (RoHC) for Voice over Internet Protocol (VoIP) calls in a cellular communications network. Notably, much of the discussion herein focuses on selective RoHC for VoIP calls in a Long Term Evolution (LTE) cellular communications network. As such, LTE terminology is oftentimes used throughout this disclosure. However, the concepts disclosed herein are not limited to LTE cellular communications networks. Rather, the concepts disclosed herein may be used to provide selective RoHC for VoIP calls in other types of cellular communications networks.

FIG. **1** illustrates a cellular communications network **10** that provides selective RoHC for VoIP calls according to one embodiment of the present disclosure. In this embodiment, the cellular communications network **10** is a LTE cellular communications network. However, as discussed above, the present disclosure is not limited thereto. The cellular communications network **10** includes a number of cells **12-1** through **12-19**, which are generally referred to herein collectively as cells **12** and individually as cell **12**. Notably, while nineteen cells **12** are illustrated in FIG. **1** for clarity and ease of discussion, it will be readily appreciated by one of ordinary skill in the art that the cellular communications network **10** may include any number of cells **12** and, in most implementations, will include a relatively large number of cells **12**.

In this embodiment, the cells **12-1** through **12-19** are served by corresponding base stations **14-1** through **14-19**, which are generally referred to herein collectively as base stations **14** and individually as base station **14**. For LTE, the base stations **14** are typically enhanced Node Bs (eNBs) but may also include low power base stations (e.g., home eNBs or femto base stations). Further, while in this embodiment each of the base stations **14** serves only one cell **12**, one or more of the base stations **14** may alternatively serve multiple cells **12**. For instance, in LTE, an eNB may serve multiple cells, or sectors. The base stations **14** provide cellular communications services (e.g., voice and data services) to mobile terminals (MTs), such as a mobile terminal **16** located in the cell **12-1**. While only one mobile terminal **16** is illustrated in FIG. **1**, it will be readily appreciated by one of ordinary skill in the art that the cellular communications network **10** will typically serve hundreds, thousands, or even millions of mobile terminals **16**.

As discussed below in detail, the base stations **14**, or at least some of the base stations **14**, provide selective RoHC for VoIP calls. In general, each of the base stations **14** has a finite amount of resources (i.e., processing cycles and memory resources) that can be used for RoHC, where these resources are referred to herein as RoHC resources. The RoHC resources of each base station **14** are logically divided into a first-come, first-serve RoHC resource pool and a selective RoHC resource pool. The first-come, first serve RoHC resource pool includes an amount of RoHC resources that is sufficient to provide RoHC for a number (N_{FCFS}) of VoIP calls, and the selective RoHC resource pool includes an amount of RoHC resources that is sufficient to provide RoHC for a number ($N_{SELECTIVE}$) of VoIP calls. Note that N_{FCFS} and $N_{SELECTIVE}$ may vary among the base stations **14** depending on the finite amount of RoHC resources of each of the base stations **14**. In one embodiment, $N_{SELECTIVE}$ is in a range of 10% to 15% of the finite amount of RoHC resources of the base station **14**, whereas N_{FCFS} is the remainder of the finite amount of RoHC resources of the base station **14**. Thus, in other words, $N_{SELECTIVE}$ is in a range of 10% to 15% of a total number of VoIP calls for which the finite amount of RoHC resources can provide RoHC, whereas N_{FCFS} is the remainder.

The base stations **14** provide selective RoHC for VoIP calls based on a coverage-based condition. More specifically, the base stations **14** provide selective RoHC for VoIP calls such that the selective RoHC resources of the base stations **14** are only available for VoIP calls for which the coverage-based condition is satisfied. In one preferred embodiment, the coverage-based condition is a Signal to Interference plus Noise Ratio (SINR) that is less than a predefined threshold. Still further, in one particular embodiment, the coverage-based condition is the same condition used to trigger Transmit Time Interval (TTI) bundling. By reserving the selective RoHC resources for VoIP calls that satisfy the coverage-based condition, the base stations **14** ensure that RoHC resources are available for VoIP calls that would most benefit from the cell coverage improvement provided by RoHC.

FIG. **2** is a flow chart that illustrates the operation of one of the base stations **14** of FIG. **1** to provide selective RoHC for a VoIP call according to one embodiment of the present disclosure. For this discussion, the base station **14** is the base station **14-1**, and the VoIP call is a VoIP call either to or from the mobile terminal **16** located in the cell **12-1** of the base station **14-1**. The process begins when a Data Radio Bearer (DRB) for a VoIP call either to or from the mobile terminal **16** is to be established. This may be when a VoIP call to or from the mobile terminal **16** is initially set up or when there is an inter-cell handover of the VoIP call to the base station **14-1**.

When a DRB for the VoIP call is to be established, the base station **14-1** determines whether RoHC resources are available in the first-come, first-serve RoHC resource pool of the base station **14-1** (step **100**). If so, the base station **14-1** establishes a DRB for the VoIP call with RoHC enabled (step **102**). Preferably, RoHC is enabled in both the uplink and downlink directions. If there are no available RoHC resources in the first-come, first serve RoHC resource pool of the base station **14-1**, the base station **14-1** establishes a DRB for the VoIP call with RoHC disabled (step **104**). Note that, after establishing the DRB with RoHC disabled, the base station **14-1** may optionally monitor the first-come, first-serve RoHC resource pool of the base station **14-1** to determine if RoHC resources subsequently become available and, if so, enable RoHC for the VoIP call.

After establishing the DRB for the VoIP call with RoHC disabled in step **104**, the base station **14-1** monitors a Radio Frequency (RF) parameter for the DRB to determine when a predefined coverage-based condition is satisfied. More specifically, the base station **14-1** obtains the RF parameter for the DRB (step **106**). The base station **14-1** then determines whether the RF parameter satisfies the predefined coverage-based condition (step **108**). In one preferred embodiment, the RF parameter is a SINR for the DRB, and the predefined coverage-based condition is a condition where the SINR is less than a predefined threshold. Further, in one preferred embodiment, the predefined coverage-based condition is the same condition used to trigger TTI bundling (e.g., the same SINR threshold used to trigger TTI bundling).

If the predefined coverage-based condition is not satisfied, the process returns to step **106** and is repeated. Conversely, if the predefined coverage-based condition is satisfied, the base station **14-1** then determines whether there are available RoHC resources in either the first-come, first-serve RoHC resource pool or the selective RoHC resource pool of the base station **14-1** (step **110**). If not, the process returns to step **106** and is repeated such that RoHC may thereafter be enabled if the predefined coverage-based condition is satisfied and RoHC resources become available. If RoHC resources are available in either the first-come, first-serve RoHC resource pool or the selective RoHC resource pool of the base station **14-1**, the base station **14-1** enables RoHC for the VoIP call (step **112**). As discussed below, in one particular embodiment, the base station **14-1** enables RoHC for the VoIP call by performing an intra-cell handover to a new DRB that has RoHC enabled. Using the process of FIG. **2**, the base station **14-1** reserves the selective RoHC resource pool for those VoIP calls that would benefit most by the cell coverage improvement provided by RoHC. Thus, the selective RoHC resource pool prevents starvation of RoHC resources for those VoIP calls that would most benefit from RoHC, while the first-come, first-serve RoHC resource pool allows RoHC for all VoIP calls as long as there are sufficient RoHC resources in the base station **14-1**.

As mentioned above, in one preferred embodiment, the RF parameter and the predefined coverage-based condition are the same as those used to trigger TTI bundling. As such, before proceeding, a brief overview of Hybrid Automatic Repeat Request (HARQ) and TTI bundling is beneficial. In LTE as well as most other modern cellular communications standards, a HARQ transmission scheme is utilized. HARQ utilizes both forward error-correction coding and Automatic Repeat Request (ARQ) to enable successful reception and decoding of transmissions under varying channel conditions. When using HARQ, the mobile terminal **16** requests retransmission for erroneously received packets as illustrated in FIG. **3**A. TTI bundling is triggered under poor radio conditions in order to reduce overhead. Notably, TTI bundling is also referred to as subframe bundling. Also, when TTI bundling is not enabled, HARQ operation is referred to as normal HARQ operation. Typically, TTI bundling is triggered, or enabled, when the SINR falls below a predefined threshold. Currently, for LTE, the HARQ transmissions are in the sequence Redundancy Version (RV) 0, RV2, RV3, RV1. As illustrated in FIG. **3**B, when using TTI bundling, the TTIs for the initial HARQ transmission and one or more subsequent HARQ retransmissions are grouped, or bundled, into successive TTIs. In this manner, the base stations **14** are enabled to successfully receive and decode the transmission with reduced overhead (i.e., without the mobile terminal **16** transmitting multiple NACKs) and with less latency.

FIG. **4** illustrates the operation of one of the base stations **14** to perform selective RoHC based on the same coverage-based condition used to trigger TTI bundling according to one embodiment of the present disclosure. For this discussion, the base station **14** is the base station **14-1**. In this example, initially, both TTI bundling and RoHC are disabled for a VoIP call either to or from the mobile terminal **16** (step **200**). As such, VoIP transmissions are transmitted over a DRB having both TTI bundling and RoHC disabled (step **202**). At some point during the VoIP call, the base station **14-1** makes a decision to enable TTI bundling for the VoIP call (step **204**). More specifically, the base station **14-1** monitors an RF parameter for the VoIP call. When the RF parameter satisfies a predefined condition for triggering TTI bundling, the base station **14-1** makes the decision to enable TTI bundling. In one preferred embodiment, the RF parameter is SINR, and the predefined condition for triggering TTI bundling is a condition that the SINR falls below a predefined threshold.

In response to the decision to enable TTI bundling, the base station **14-1** performs a selective RoHC admission process in order to decide whether RoHC resources are available (step **206**). In general, the base station **14-1** determines whether RoHC resources are available in either the first-come, first-serve RoHC resource pool or the selective RoHC resource pool of the base station **14-1**. In this example, the base station **14-1** determines that RoHC resources are available. As such, the base station **14-1** initiates an intra-cell handover to enable both TTI bundling and RoHC. Notably, in this embodiment, the decision on whether to selectively enable RoHC for the VoIP call is piggy-backed on the decision to enable TTI bundling.

For LTE, in order to perform the intra-cell handover, the base station **14-1** first sends an RRCConnectionReconfigurationRequest message to the mobile terminal **16** in order to request a new DRB for the VoIP call having both TTI bundling and RoHC enabled (step **208**). From this point, the conventional LTE intra-cell handover procedure is performed. Specifically, the mobile terminal **16** sends a random access preamble to the base station **14-1** (step **210**). In response, the base station **14-1** then returns a random access response to the mobile terminal **16** (step **212**). At that point, the mobile terminal **16** sends an RRCConnectionReconfigurationConfirm message to the base station **14-1** confirming that both TTI bundling and RoHC are enabled for the new DRB for the VoIP call (step **214**). At this point, the intra-cell handover is complete. Using the intra-cell handover, the base station **14-1** simultaneously enables both TTI bundling and RoHC for the VoIP call. Notably, in LTE, TTI bundling is only enabled in the uplink. However, RoHC is preferably enabled for the DRB in both the uplink and downlink directions.

Once the intra-cell handover is complete, the base station **14-1** updates the appropriate RoHC resource pool to indicate that the RoHC resources used for the new DRB are no longer available (step **216**). Note that while in FIG. **4** the appropriate RoHC resource pool is updated after the intra-cell handover has been completed, the base station **14-1** may alternatively update the appropriate RoHC resource pool at any time between the decision made in step **206** and the completion of the intra-cell handover. For example, the base station **14-1** may update the appropriate RoHC resource pool after making the decision in step **206** and before sending the RRCConnectionReconfigurationRequest in step **208** in order to reserve RoHC resources for the new DRB. In this case, if the intra-cell handover fails, the base station **14-1** updates the appropriate RoHC resource pool to release the RoHC resources that were reserved for the new DRB. Lastly, VoIP transmissions for the VoIP call are transmitted over the new DRB having both TTI bundling and RoHC enabled (step **218**).

FIG. **5** is a flow chart that illustrates the operation of the base station **14-1** of FIG. **4** to perform a selective RoHC admission process and, if RoHC is enabled, update the appropriate RoHC resource pool according to one embodiment of the present disclosure. Thus, in general, FIG. **5** illustrates steps **206** and **216** of FIG. **4** in more detail according to one embodiment of the present disclosure. Again, for this discussion, the base station **14** is the base station **14-1**. However, this discussion is equally applicable to the other base stations **14**. First, the base station **14-1** determines whether an intra-cell handover has been triggered to enable TTI bundling (step **300**). More specifically, as discussed above, the base station **14-1** determines whether the RF parameter for the DRB for the VoIP call satisfies the predefined condition for triggering TTI bundling. Again, in one preferred embodiment, the RF parameter is SINR, and the predefined condition for triggering TTI bundling is the condition that the SINR falls below a predefined threshold for triggering TTI bundling.

If an intra-cell handover has not been triggered to enable TTI bundling, the process returns to step **300** and waits until an intra-cell handover has been triggered to enable TTI bundling. Once an intra-cell handover has been triggered to enable TTI bundling, the base station **14-1** determines whether RoHC resources are available in the first-come, first-serve RoHC resource pool of the base station **14-1** (step **302**). If so, the base station **14-1** initiates an intra-cell handover of the VoIP call to a new DRB with both TTI bundling and RoHC enabled (step **304**). The base station **14-1** then updates the first-come, first-serve RoHC resource pool to reflect that the RoHC resources used for the new DRB are no longer available (step **306**). For example, the base station **14-1** may maintain a counter that is equal the number of VoIP calls that are utilizing RoHC resources from the first-come, first-serve RoHC resource pool. So, if all of the RoHC resources in the first-come, first-serve RoHC resource pool are available, then the counter would be equal to 0. Conversely, if none of the RoHC resources in the first-come, first-serve RoHC resource pool are available, then the counter would be equal to N_{FCFS}. Thus, in this example, the base station **14-1** updates the first-come, first-serve RoHC resource pool by increasing the counter by 1. When the RoHC resources are subsequently released, the counter is decreased by 1.

Returning to step **302**, if there are no available RoHC resources in the first-come, first-serve RoHC resource pool, the base station **14-1** determines whether there are available RoHC resources in the selective RoHC resource pool (step **308**). If not, the base station **14-1** initiates an intra-cell handover of the VoIP call to a new DRB with TTI bundling enabled and RoHC disabled (step **310**). Notably, if step **310** is triggered often, allocation of the RoHC resources of the base station **14-1** to the first-come, first-serve RoHC resource pool and the selective RoHC resource pool may be rebalanced in order to allocate more RoHC resources to the selective RoHC resource pool. This re-balancing may be performed programmatically by the base station **14-1** in response to the base station **14-1** detecting that step **310** is performed often (e.g., for at least a predefined threshold number or percentage of intra-cell handovers triggered to enable TTI bundling). Alternatively, the re-balancing may be performed manually by an operator of the base station **14-1**.

Returning to step **308**, if RoHC resources are available in the selective RoHC resource pool, the base station **14-1** initiates an intra-cell handover of the VoIP call to a new DRB with both TTI bundling and RoHC enabled (step **312**). The base station **14-1** then updates the selective RoHC resource pool to reflect that the RoHC resources used for the new DRB are no longer available (step **314**). For example, the base station **14-1** may maintain a counter that is equal the number of VoIP calls that are utilizing RoHC resources from the selective RoHC resource pool. So, if all of the RoHC resources in the selective RoHC resource pool are available, then the counter would be equal to 0. Conversely, if none of the RoHC resources in the selective RoHC resource pool are available, then the counter would be equal to $N_{SELECTIVE}$. Thus, in this example, the base station **14-1** updates the selective RoHC resource pool by increasing the counter by 1. When the RoHC resources are subsequently released, the counter is decreased by 1.

FIG. **6** is a block diagram of one of the base stations **14** of FIG. **1** according to one embodiment of the present disclosure. The base station **14** includes a transceiver subsystem **18** and a processing subsystem **20**. The transceiver subsystem **18** generally includes analog and, in some embodiments, digital components for wirelessly sending and receiving messages to and from the mobile terminals **16** in the cellular communications network **10**. In particular embodiments, the transceiver subsystem **18** may represent or include a radio-frequency (RF) transceiver, or a separate RF transmitter and receiver, capable of transmitting messages and/or other suitable information wirelessly to the mobile terminal **16**.

The processing subsystem **20** is implemented in hardware or a combination of hardware and software. Among other things, the processing subsystem **20** performs selective RoHC as described herein. In particular embodiments, the processing subsystem **20** may comprise, for example, one or several general-purpose or special-purpose microprocessors or other microcontrollers programmed with suitable software and/or firmware to carry out some or all of the functionality of the base station **14** described herein. In addition or alternatively, the processing subsystem **20** may comprise various digital hardware blocks (e.g., one or more Application Specific Integrated Circuits (ASICs), one or more off-the-shelf digital and analog hardware components, or a combination thereof) configured to carry out some or all of the functionality of the base station **14** described herein.

Additionally, in particular embodiments, the above described functionality of base station **14** may be implemented, in whole or in part, by the processing subsystem **20** executing software or other instructions stored on a non-transitory computer-readable medium, such as random access memory (RAM), read only memory (ROM), a magnetic storage device, an optical storage device, or any other suitable type of data storage components.

FIG. **7** is a block diagram of the mobile terminal **16** of FIG. **1** according to one embodiment of the present disclosure. The mobile terminal **16** includes a transceiver subsystem **22** and a processing subsystem **24**. The transceiver subsystem **22** generally includes analog and, in some embodiments, digital components for wirelessly sending and receiving messages to and from the base stations **14** in the cellular communications network **10**. In particular embodiments, the transceiver subsystem **22** may represent or include an RF transceiver, or a separate RF transmitter and receiver, capable of transmitting messages and/or other suitable information wirelessly to the base stations **14**.

The processing subsystem **24** is implemented in hardware or a combination of hardware and software. In general, the processing subsystem **24** enables the mobile terminal **16** to perform the functions of the mobile terminal **16** described herein. In particular embodiments, the processing subsystem **24** may comprise, for example, one or several general-purpose or special-purpose microprocessors or other microcontrollers programmed with suitable software and/or firmware to carry out some or all of the functionality of the mobile terminal **16** described herein. In addition or alternatively, the processing subsystem **24** may comprise various digital hardware blocks (e.g., one or more ASICs, one or more off-the-shelf digital and analog hardware components, or a combination thereof) configured to carry out some or all of the functionality of the mobile terminal **16** described herein. Additionally, in particular embodiments, the above described functionality of the mobile terminal **16** may be implemented, in whole or in part, by the processing subsystem **24** executing software or other instructions stored on a non-transitory computer-readable medium, such as RAM, ROM, a magnetic storage device, an optical storage device, or any other suitable type of data storage components.

The following acronyms are used throughout this disclosure.

ARQ Automatic Repeat Request
ASIC Application Specific Integrated Circuit
DRB Data Radio Bearer
eNB Enhanced Node B
HARQ Hybrid Automatic Repeat Request
HO Handover
IP Internet Protocol
LTE Long Term Evolution
MT Mobile Terminal
RAM Random Access Memory
RF Radio Frequency
RoHC Robust Header Compression
ROM Read Only Memory
RV Redundancy Version
SINR Signal to Interference plus Noise Ratio
TTI Transmit Time Interval
VoIP Voice over Internet Protocol

Those skilled in the art will recognize improvements and modifications to the preferred embodiments of the present disclosure. All such improvements and modifications are considered within the scope of the concepts disclosed herein and the claims that follow.

What is claimed is:

1. A method of operation of a base station in a cellular communications network, comprising:

establishing a data radio bearer between the base station and a mobile terminal for a Voice-Over Internet Protocol (VoIP) call;

determining that a radio frequency parameter for the data radio bearer satisfies a predefined coverage-based condition; and

in response to determining that the radio frequency parameter for the data radio bearer satisfies the predefined coverage-based condition, enabling Robust Header Compression (RoHC) for the VoIP call wherein enabling RoHC for the VoIP call comprises performing an intra-cell handover of the VoIP call from the data radio bearer to a new data radio bearer that has RoHC enabled.

2. The method of claim **1** further comprising:

determining whether the base station has available RoHC resources; and

wherein enabling RoHC for the VoIP call comprises enabling RoHC for the VoIP call if the base station has available RoHC resources.

3. A method of operation of a base station in a cellular communications network, comprising:

establishing a data radio bearer between the base station and a mobile terminal for a Voice-Over Internet Protocol (VoIP) call;

determining that a radio frequency parameter for the data radio bearer satisfies a predefined coverage-based condition, wherein the radio frequency parameter is a Signal-to-Interference-plus-Noise Ratio (SINR) parameter, and the predefined coverage-based condition is a predefined SINR threshold for triggering Transmission Time Interval (TTI) bundling; and

in response to determining that the radio frequency parameter for the data radio bearer satisfies the predefined coverage-based condition, enabling Robust Header Compression (RoHC) for the VoIP call.

4. The method of claim **3** wherein:

determining that the radio frequency parameter for the data radio bearer satisfies the predefined coverage-based condition comprises determining that the SINR parameter is less than the predefined SINR threshold for TTI bundling; and

enabling RoHC for the VoIP call comprises enabling both TTI bundling and RoHC for the VoIP call in response to determining that the SINR parameter is less than the predefined SINR threshold for TTI bundling.

5. The method of claim **4** further comprising:

determining whether the base station has available RoHC resources;

wherein enabling both TTI bundling and RoHC for the VoIP call comprises enabling both TTI bundling and RoHC for the VoIP call if the base station has available RoHC resources.

6. The method of claim **3** wherein enabling both TTI bundling and RoHC for the VoIP call comprises simultaneously enabling both TTI bundling and RoHC for the VoIP call.

7. The method of claim **6** wherein simultaneously enabling both TTI bundling and RoHC for the VoIP call comprises performing an intra-cell handover of the VoIP call from the data radio bearer to a new data radio bearer that has both TTI bundling and RoHC enabled.

8. The method of claim **6** further comprising:

determining whether the base station has available RoHC resources;

wherein simultaneously enabling both TTI bundling and RoHC for the VoIP call comprises performing an intra-cell handover of the VoIP call from the data radio bearer to a new data radio bearer that has both TTI bundling and RoHC enabled if the base station has available RoHC resources.

9. The method of claim **8** wherein the base station has a finite amount of RoHC resources that are logically divided into a first-come, first-serve RoHC resource pool and a selective RoHC resource pool, and determining whether the base station has available RoHC resources comprises:

determining whether there are available RoHC resources in the first-come, first-serve RoHC resource pool; and

if there are no available resources in the first-come, first-serve RoHC resource pool, determining whether there are available RoHC resources in the selective RoHC resource pool.

10. A base station in a cellular communications network, comprising:

a transceiver subsystem; and

a processing subsystem associated with the transceiver subsystem configured to:

establish, via the transceiver subsystem, a data radio bearer between the base station and a mobile terminal for a Voice-Over Internet Protocol (VoIP) call;

determine that a radio frequency parameter for the data radio bearer satisfies a predefined coverage-based condition; and

in response to determining that the radio frequency parameter for the data radio bearer satisfies the predefined coverage-based condition, enable Robust Header Compression (RoHC) for the VoIP call, wherein, in order to enable RoHC for the call, the processing subsystem is further configured to perform an intra-cell handover of the VoIP call from the data radio bearer to a new data radio bearer that has RoHC enabled.

11. The base station of claim **10** wherein the processing subsystem is further configured to:

determine whether the base station has available RoHC resources; and

enable RoHC for the VoIP call if the base station has available RoHC resources.

12. A base station in a cellular communications network, comprising:

a transceiver subsystem; and

a processing subsystem associated with the transceiver subsystem configured to:

establish, via the transceiver subsystem, a data radio bearer between the base station and a mobile terminal for a Voice-Over Internet Protocol (VoIP) call;

determine that a radio frequency parameter for the data radio bearer satisfies a predefined coverage-based condition, wherein the radio frequency parameter is a Signal-to-Interference-plus-Noise Ratio (SINR) parameter, and the predefined coverage-based condition is a predefined SINR threshold for triggering Transmission Time Interval (TTI) bundling; and

in response to determining that the radio frequency parameter for the data radio bearer satisfies the predefined coverage-based condition, enable Robust Header Compression (RoHC) for the VoIP call.

13. The base station of claim **12** wherein the processing subsystem is further configured to:

determine that the SINR parameter is less than the predefined SINR threshold for TTI bundling; and

enable both TTI bundling and RoHC for the VoIP call in response to determining that the SINR parameter is less than the predefined SINR threshold for TTI bundling.

14. The base station of claim **13** wherein the processing subsystem is further configured to:

determine whether the base station has available RoHC resources; and

enable both TTI bundling and RoHC for the VoIP call if the base station has available RoHC resources.

15. The base station of claim **12** wherein the processing subsystem is further configured to simultaneously enable both TTI bundling and RoHC for the VoIP call if the base station has available RoHC resources.

16. The base station of claim **15** wherein the processing subsystem is further configured to simultaneously enabling both TTI bundling and RoHC for the VoIP call via an intra-cell handover of the VoIP call from the data radio bearer to a new data radio bearer that has both TTI bundling and RoHC enabled.

17. The base station of claim **15** wherein the processing subsystem is further configured to:

determine whether the base station has available RoHC resources; and

simultaneously enable both TTI bundling and RoHC for the VoIP call via the intra-cell handover of the VoIP call from the data radio bearer to the new data radio bearer that has both TTI bundling and RoHC enabled if the base station has available RoHC resources.

18. The base station of claim **17** wherein the processing subsystem comprises a finite amount of RoHC resources that are logically divided into a first-come, first-serve RoHC resource pool and a selective RoHC resource pool, and, in order to determine whether the processing subsystem has available RoHC resources, the processing subsystem is further configured to:

determine whether there are available RoHC resources in the first-come, first-serve RoHC resource pool; and

if there are no available resources in the first-come, first-serve RoHC resource pool, determine whether there are available RoHC resources in the selective RoHC resource pool.

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